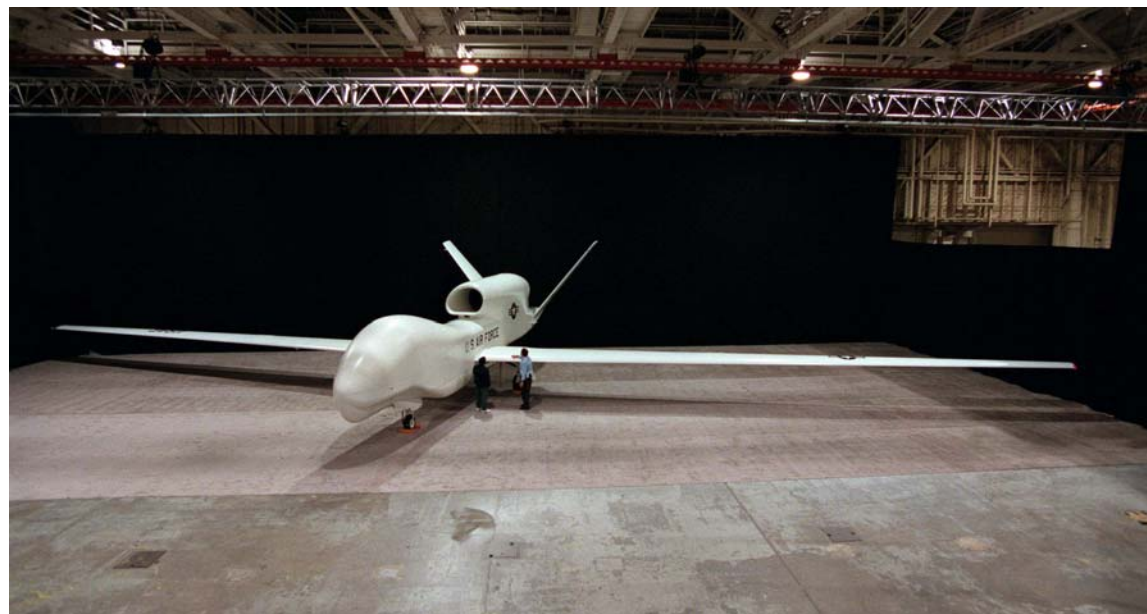


SPATIAL DISORIENTATION COUNTERMEASURES (SD CM)



Potential SD Problems for the UAV Controller
(In Both Supervised & Directly Controlled Modes)
Joint Cockpit Office--WPAFB, OH

4 - 5 Sep 02

Bill Ercoline & Rick Evans, Veridian (AFRL/HEM)

SD CM UAV Overview

- SD Background
 - Definition
 - Types
 - Factors
- Visual Misperceptions
 - Ambient
 - Focal
- Summary



Global Hawk

The Desire for Flight

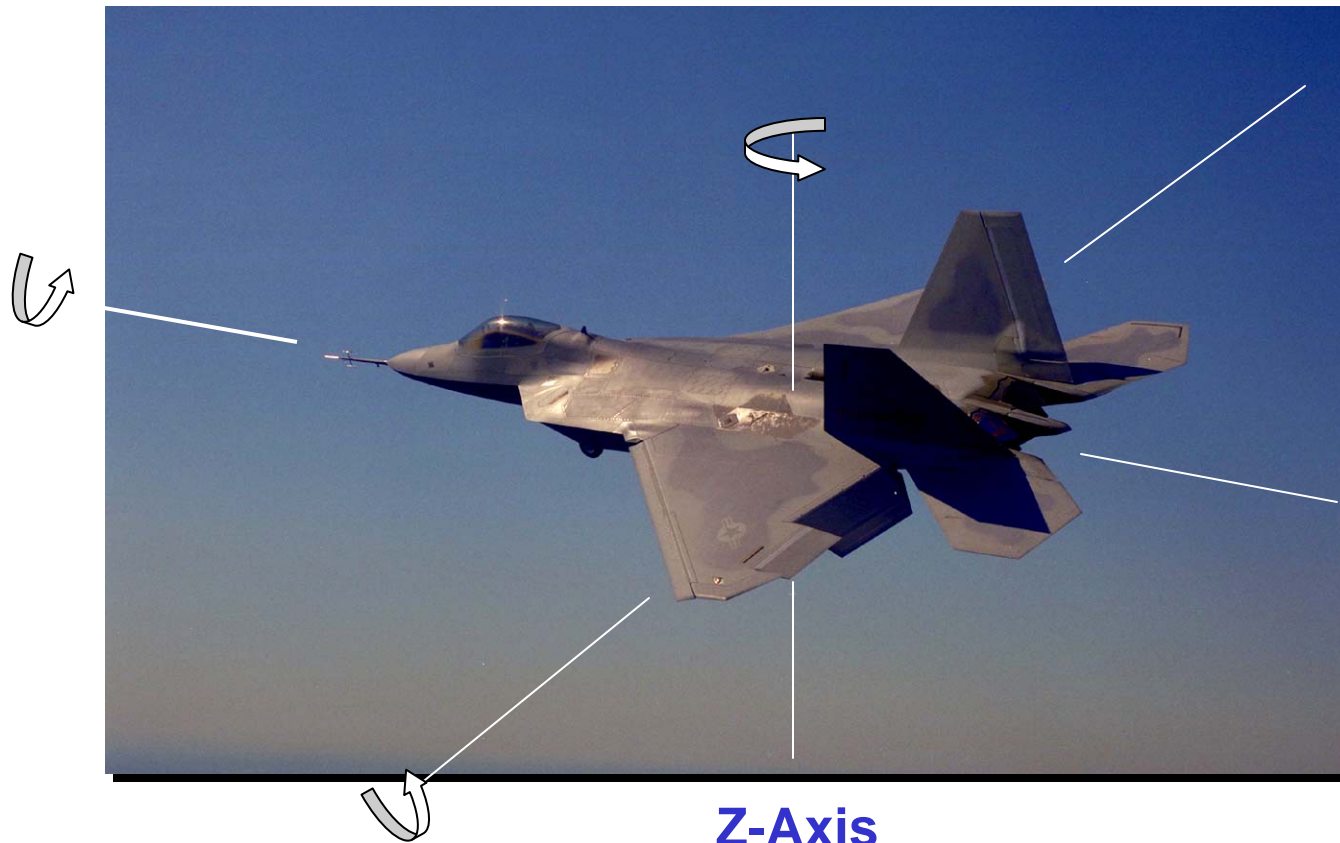
“I sometimes think that the desire to fly after the fashion of birds is an idea handed down to us by our ancestors who, in their grueling travels across trackless lands in prehistoric times, looked enviously on the birds soaring freely through space, at full speed, above all obstacles, on the infinite highway of the air.”

Wilbur Wright, 1908



SD CM UAV

Axes of Motion



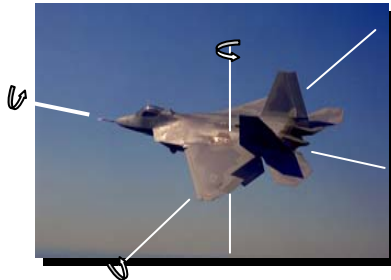
Y-Axis
Pitch Rotation
Lateral Trans.

X-Axis
Roll Rotation
Longitudinal
Translation

Z-Axis
Yaw Rotation
Vertical Translation

SD CM UAV

Spatial-Temporal Description



Linear

Angular

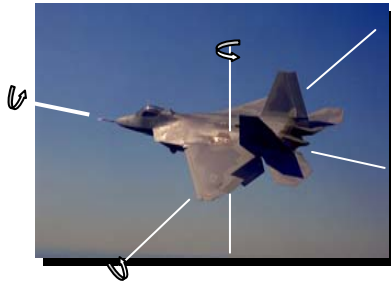
Displacement X Y Z θ_x θ_y θ_z

Velocity \dot{X} \dot{Y} \dot{Z} $\dot{\theta}_x$ $\dot{\theta}_y$ $\dot{\theta}_z$

Acceleration \ddot{X} \ddot{Y} \ddot{Z} $\ddot{\theta}_x$ $\ddot{\theta}_y$ $\ddot{\theta}_z$

SD CM UAV

Spatial-Temporal Description (display terms)



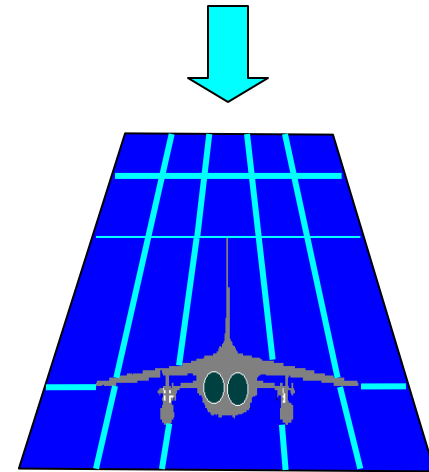
	<i>Linear</i>			<i>Angular</i>		
Displacement	X	Y	Z	θ_x	θ_y	θ_z
	*	*	(alt)	(rol)	(pit)	(yaw)
Velocity	\dot{X}	\dot{Y}	\dot{Z}	$\dot{\theta}_x$	$\dot{\theta}_y$	$\dot{\theta}_z$
	(a/s)	(s/s)	(v/s)			
Acceleration	\ddot{X}	\ddot{Y}	\ddot{Z}	$\ddot{\theta}_x$	$\ddot{\theta}_y$	$\ddot{\theta}_z$
			(G)			

* Parameters for geographic orientation (lat/long or crs/dme)
Principal SO parameters for fixed wing in blue

SD CM UAV

Formal Definition of SD

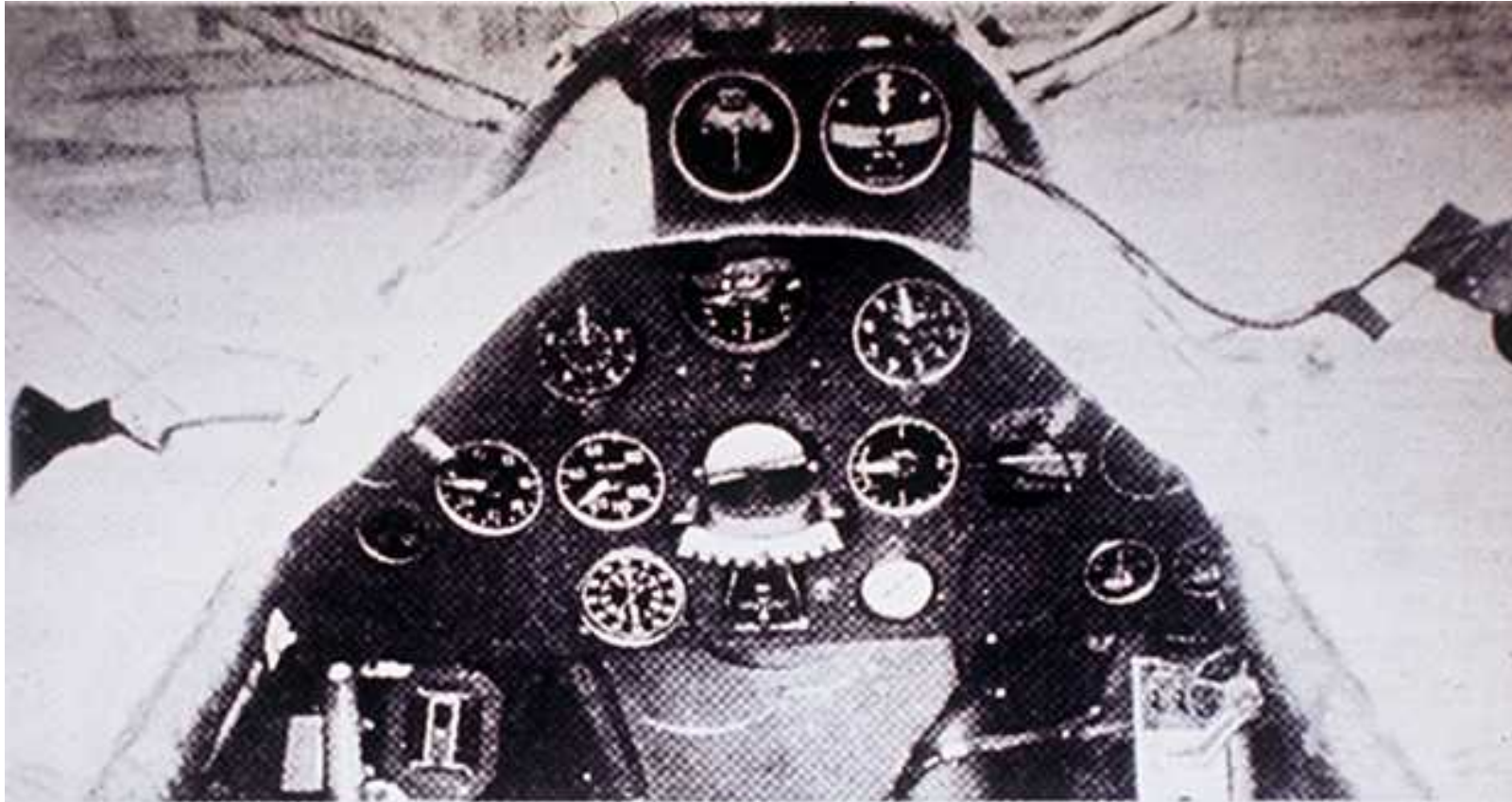
“[A failure] to sense correctly the position, motion or attitude of his aircraft or of himself [herself] within the fixed coordinate system provided by the surface of the earth and the gravitational vertical.



In addition, errors in perception by the aviator of his position, motion or attitude with respect to his aircraft, or of his own aircraft relative to other aircraft, may also be embraced within a broader definition of spatial disorientation in flight. -- Alan Benson (1978)

The Cockpit That Defined The Way Flight Information Would Be Displayed

The First “Blind” Sortie; Doolittle and Sperry, 1929



This instrument panel opened a new era of flight.

JIMMY DOOLITTLE

Integrated “Glass” Display

Spatial Orientation

Basic Information:

1. Pitch → Attitude
2. Bank → Attitude
3. Altitude
4. Airspeed

NOTE: Symbology and mechanization define magnitude, direction, and time-rate of change (i.e., motion)

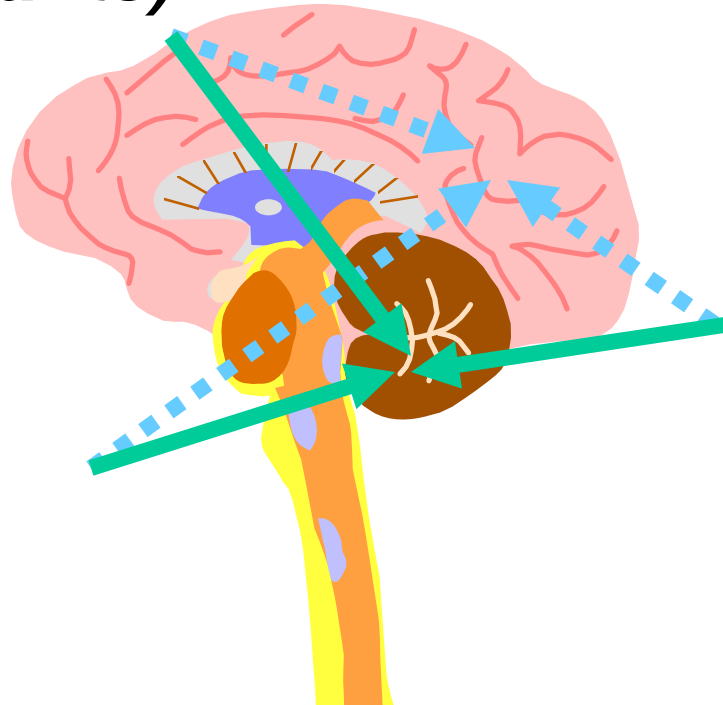


Primary Sensory Functions Used For Spatial Orientation

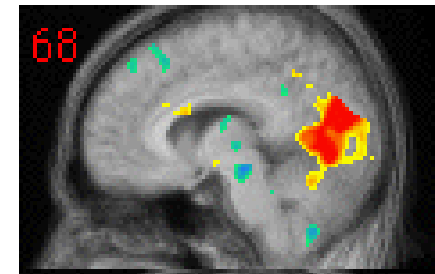
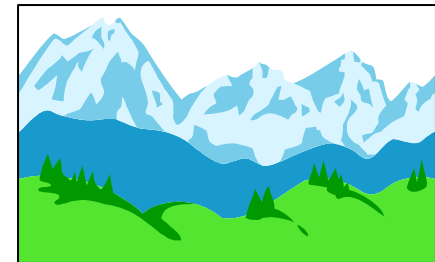
Somatosensory (*seat-of-the-pants*)



Vestibular



Visual

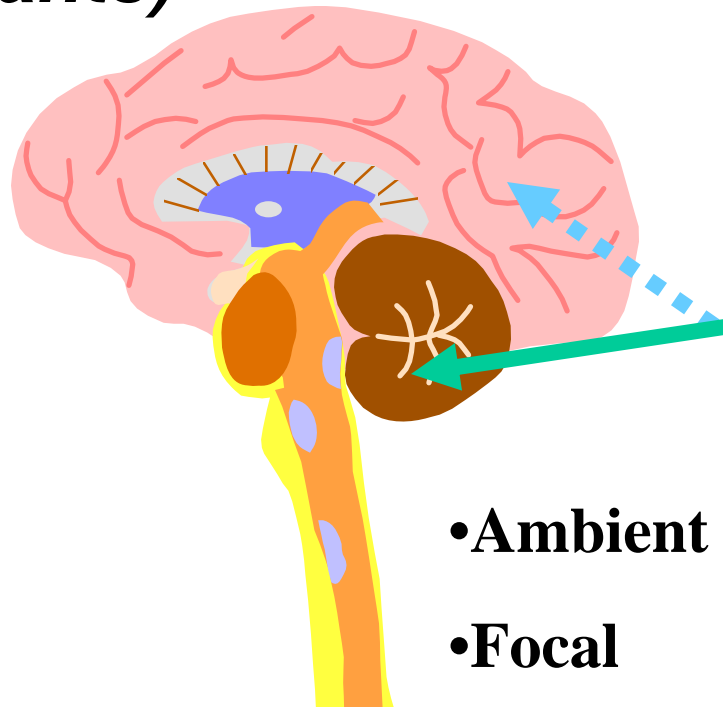


Primary Sensory Functions Used For Spatial Orientation (UAV)

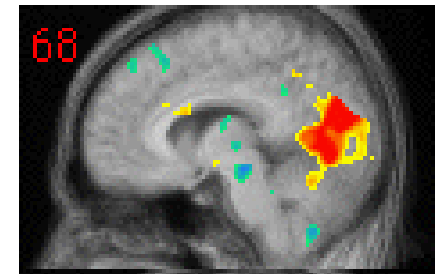
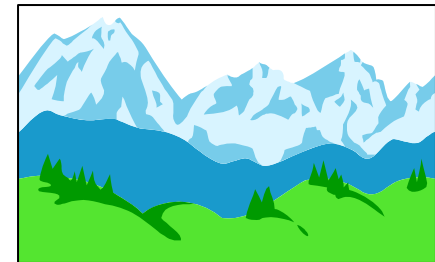
Somatosensory (*seat-of-the-pants*)



Vestibular

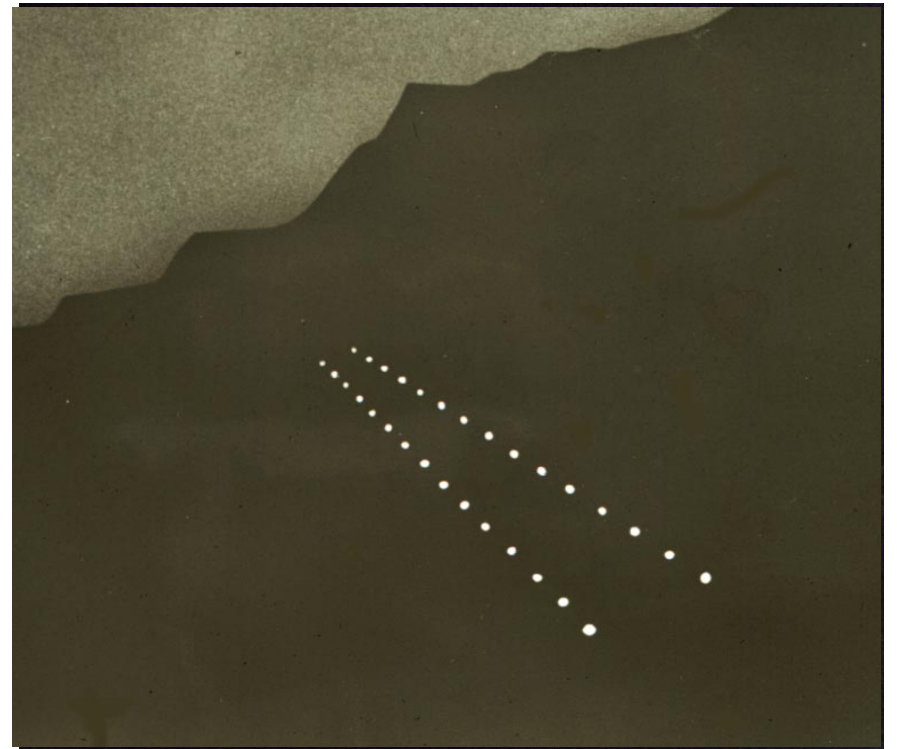


Visual

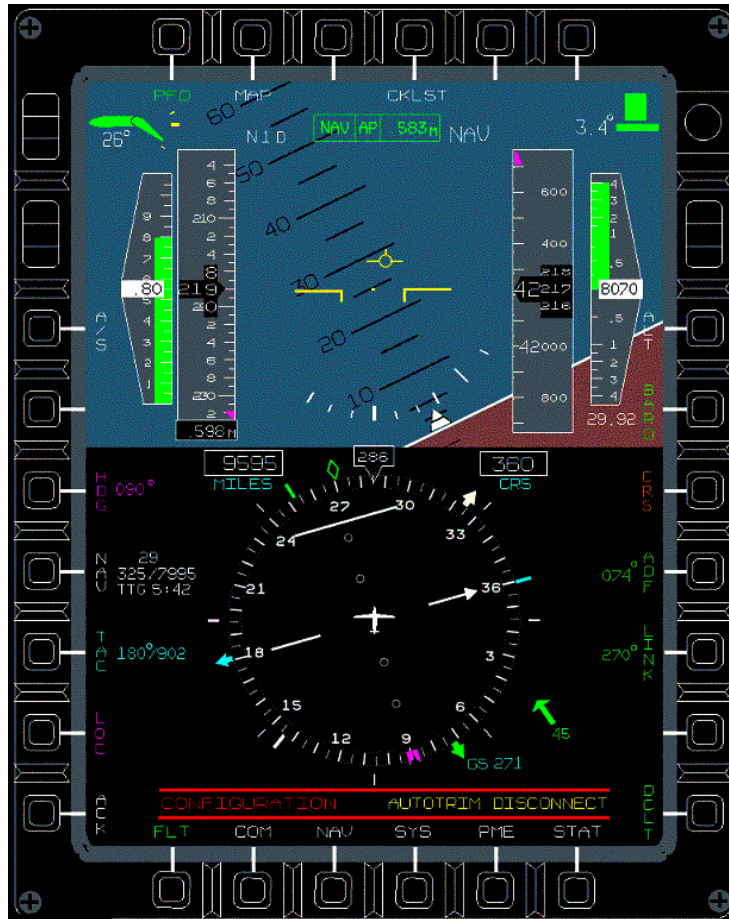


- Ambient
- Focal

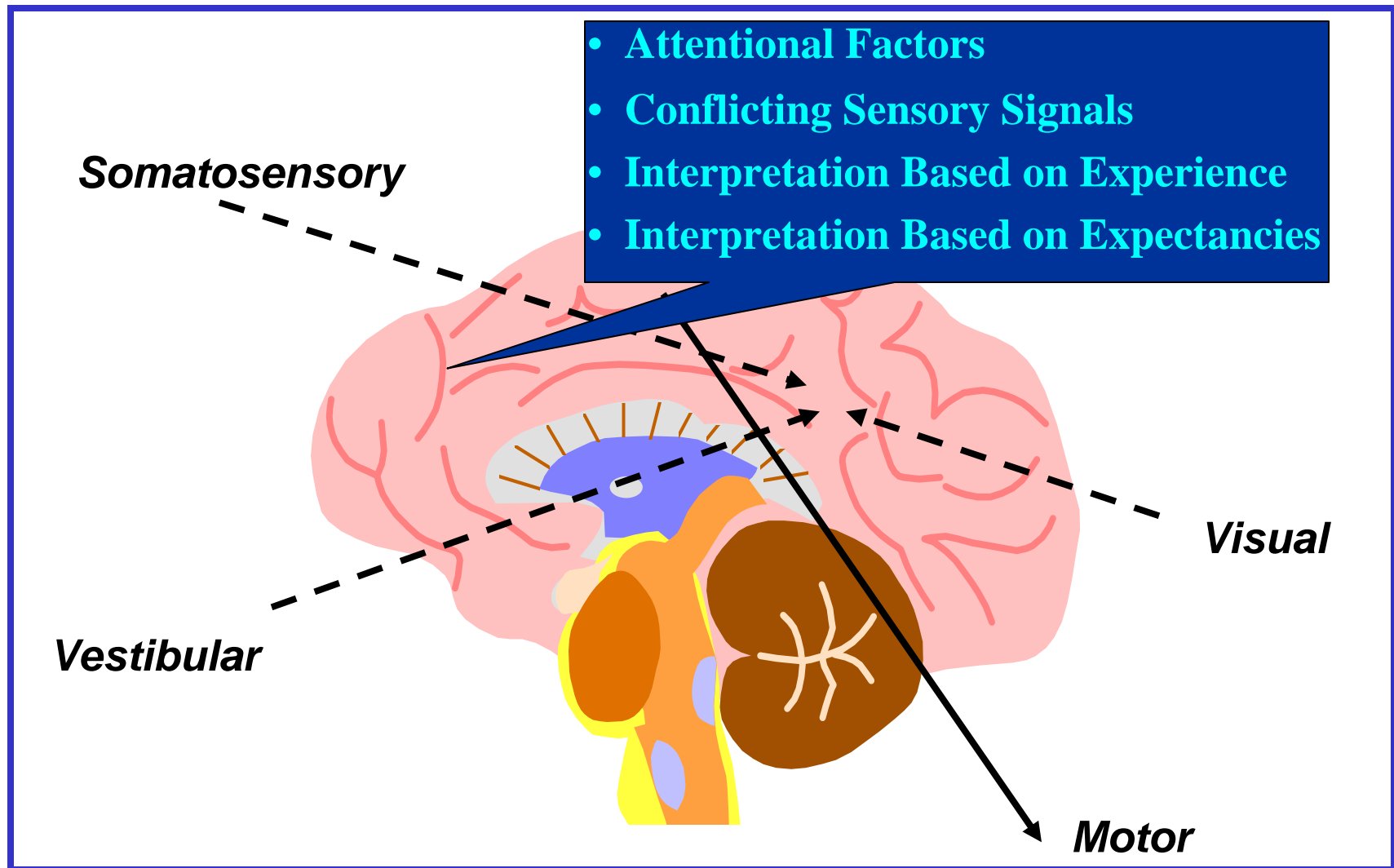
Natural Orientation Appears To Come From the Ambient Mode...



Although For Spatial Awareness In Flight We Rely Heavily On The Focal Mode...



Thus, SD Can Be Attributable To Both Cortical and Sub-cortical Factors



How Does SD Manifest Itself?



SD CM UAV

Spatial Disorientation Types

TYPE I -- *Unrecognized*

- About 80% of all Class A SD accidents
- Pilot does not consciously perceive any manifestation of SD
- Most often occurs when pilot breaks cross-check
- Most likely to lead to controlled flight into terrain

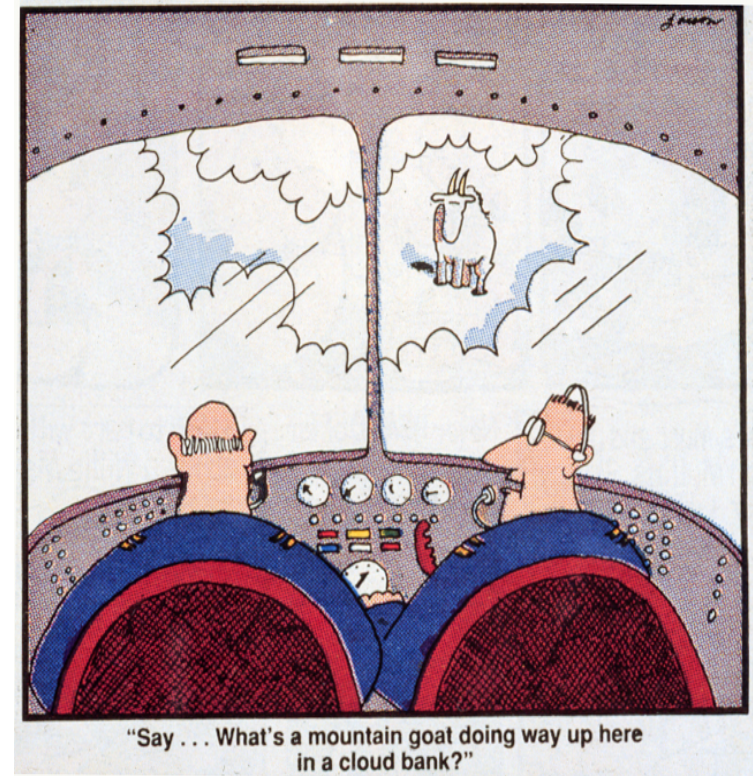


SD CM UAV

Spatial Disorientation Types

TYPE II -- *Recognized*

- About 20% of all SD Class A accidents
- Conflict between “Natural” and “Synthetic” SD percepts may occur
- Pilot consciously perceives a manifestation of SD but may not attribute it to SD itself
- Instrument malfunction is often suspected



SD CM UAV

Spatial Disorientation Types

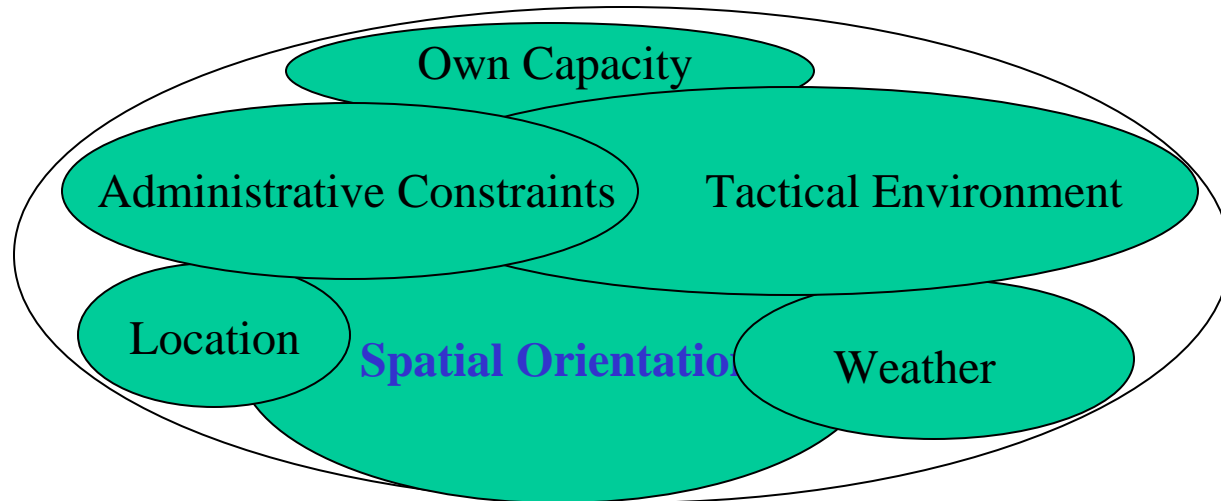
TYPE III -- *Incapacitating*

- Experienced by 10-15% of aviators
- Vestibulo-Ocular Disorganization (i.e., uncontrollable nystagmus)
- Motor Conflict (e.g., “Giant Hand”)
- Temporal Distortion
- Dissociation (“Break-Off”)



SD CM UAV

Relationship to Situation Awareness



If the situation about which a pilot is unaware is the motion/direction of any of the control or performance flight parameters, then the pilot has *spatial disorientation* as well as loss of situation awareness (LSA).

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Issues

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - Misjudgment of object-size (no size-constancy)
 - Misjudgment of object-alignment
 - Misjudgment of object-distance
 - Masking
 - Misjudgment of object-motion
- **Viewing-Device Distortions (LEP, NVG)**

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

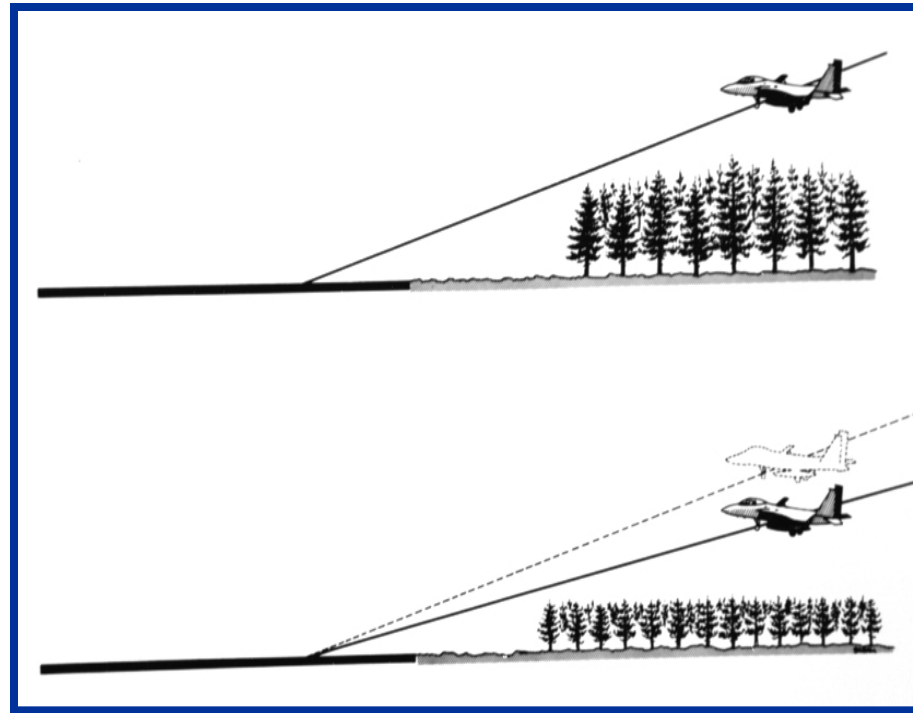
- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - **Misjudgment of object size**

VISUAL ORIENTATION ILLUSIONS

Misjudgment of Object Size

Examples of Size-Constancy Effects

- Runways
- Terrain
- Other Aircraft



Aleutian Island Tree Illusion

VISUAL ORIENTATION ILLUSIONS

Runway Size Effects



Shaw AFB
1 m from runway



Ramstein AFB
300 ft from runway

Ramstein AFB
1 m from runway



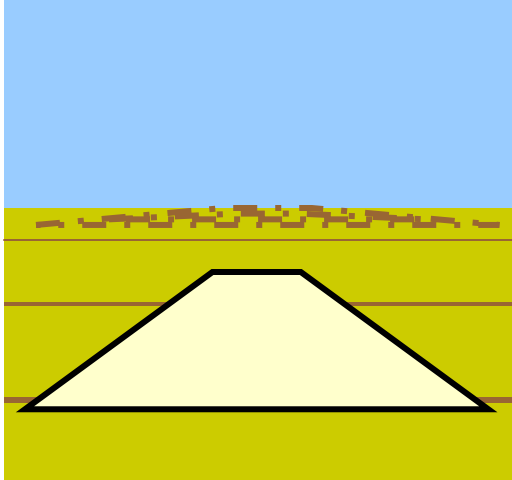
SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - Misjudgment of object-size
 - **Misjudgment of object-alignment**

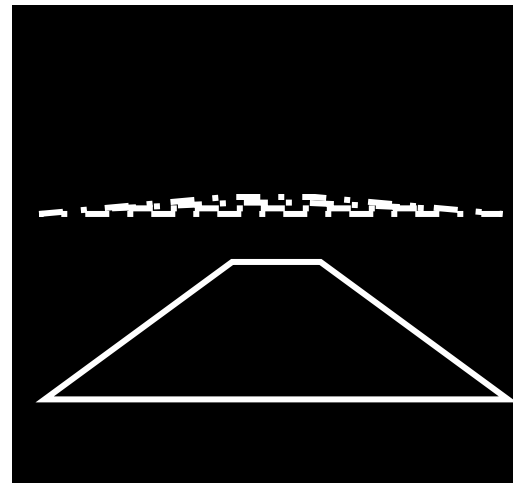
VISUAL ORIENTATION ILLUSIONS

Black-Hole Approach



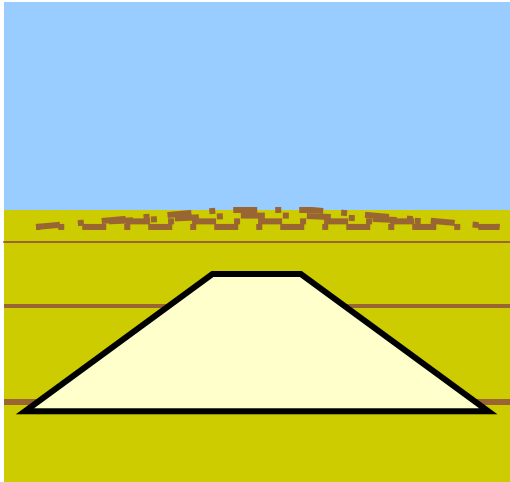
Normal Day-time Approach

*Normal Night-time
Approach*



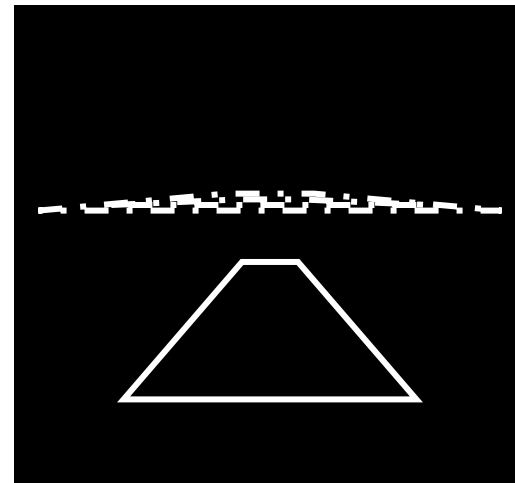
VISUAL ORIENTATION ILLUSIONS

Black-Hole Approach



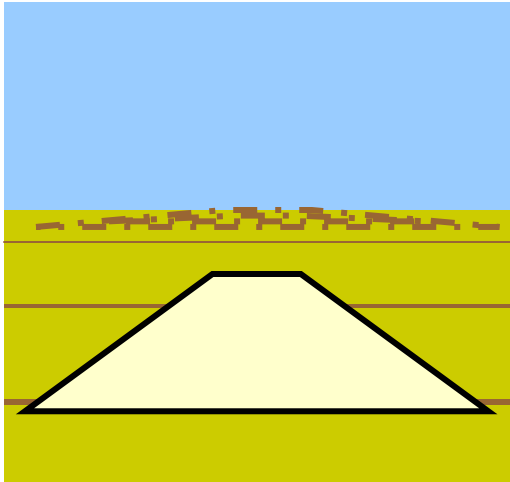
Normal Day-time Approach

*Night-time Approach
Narrow Runway*



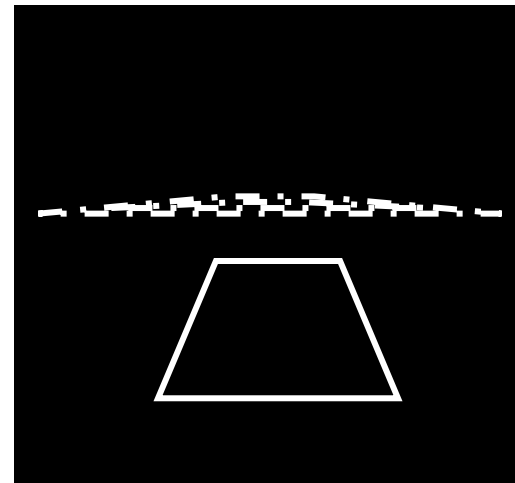
VISUAL ORIENTATION ILLUSIONS

Black-Hole Approach



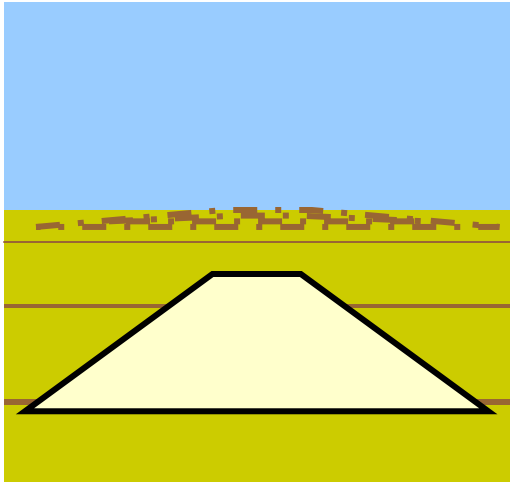
Normal Day-time Approach

Night-time Approach
NR + Upsloping Runway



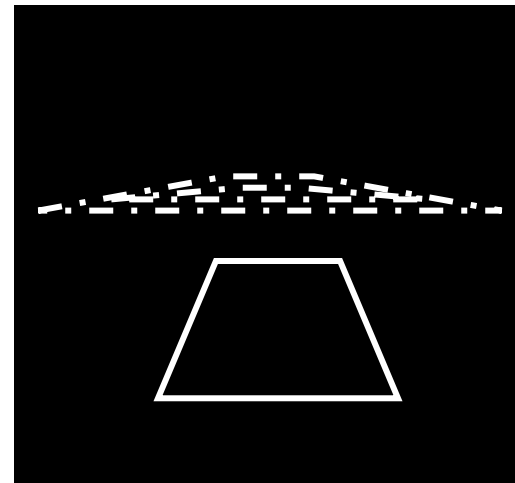
VISUAL ORIENTATION ILLUSIONS

Black-Hole Approach



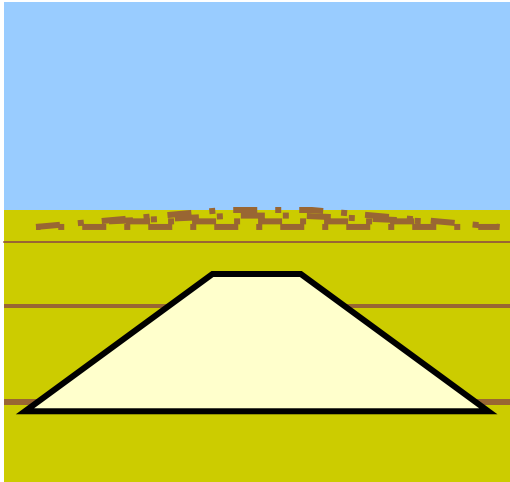
Normal Day-time Approach

Night-time Approach
NR + UR +
Rising Background Terrain



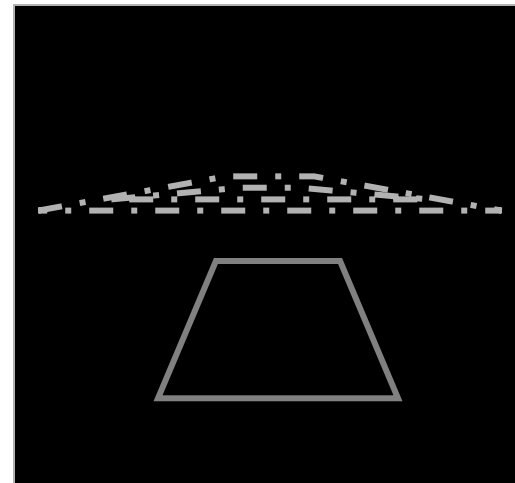
VISUAL ORIENTATION ILLUSIONS

Black-Hole Approach



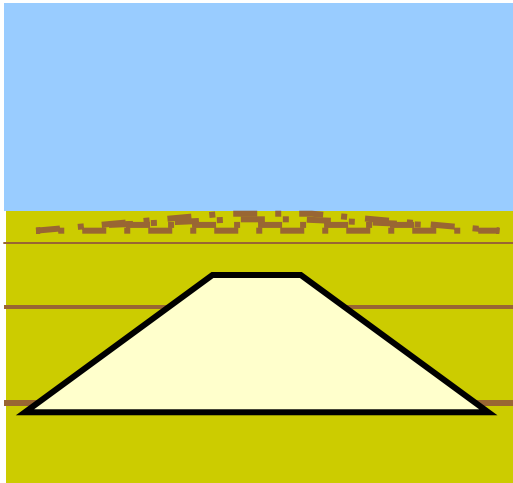
Normal Day-time Approach

Night-time Approach
NR + US + RBT + Fog

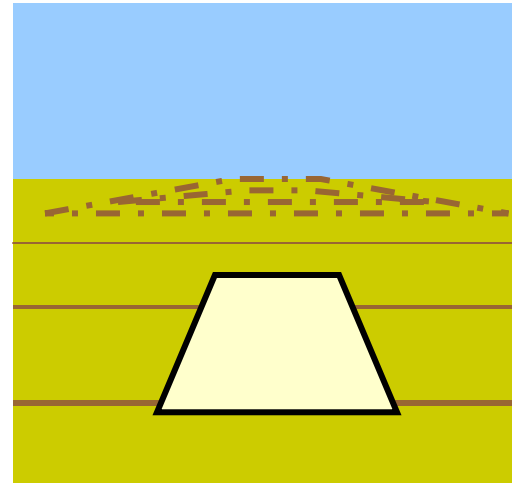


VISUAL ORIENTATION ILLUSIONS

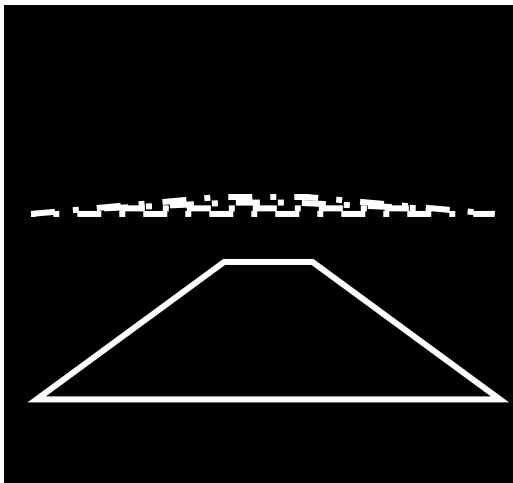
Black-Hole Approach



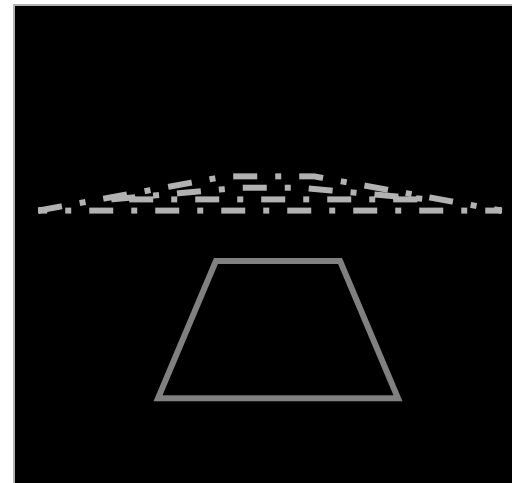
Normal Day-Time Approach



Day-Time Approach (NR + UR + RBT)



Normal Night-Time Approach



Night-Time Approach (NR + UR + RBT)

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

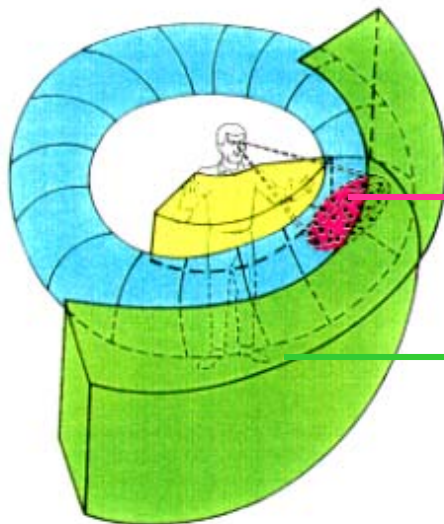
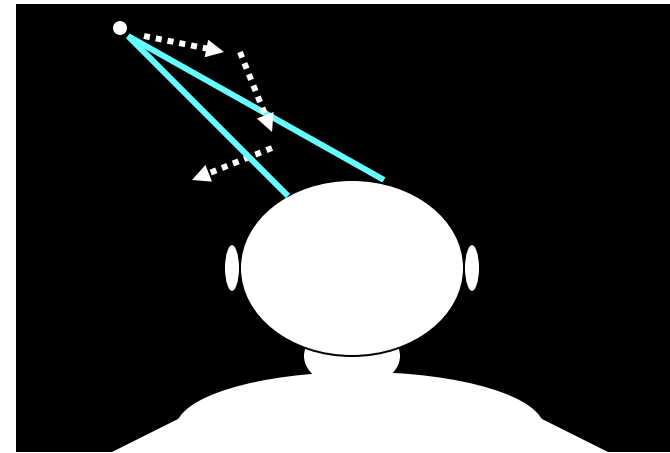
- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - Misjudgment of object-size (no size-constancy)
 - Misjudgment of object-alignment
 - Misjudgment of object-distance
 - Masking
 - Misjudgment of object-motion

VISUAL ORIENTATION ILLUSIONS

Apparent Motion

Autokinesis

- Movement of A Small Spot in A Darkened Environment
- Caused By Unregistered Eye Movements
- Reflects “Failure” of Visual Dominance

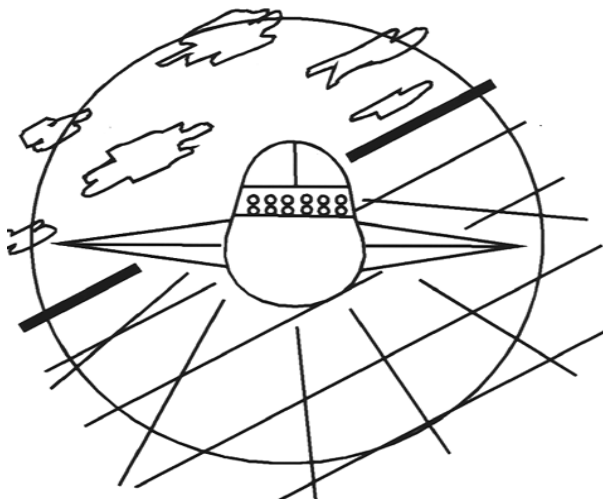


No Visual Dominance

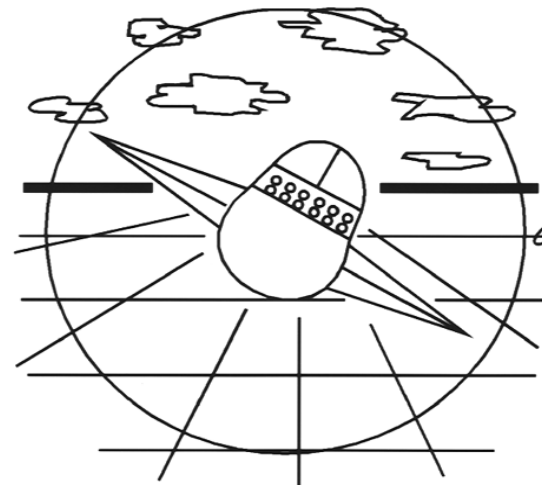
Visual Dominance

Relative Motion—Attitude Concepts

Comparison of the two attitude concepts



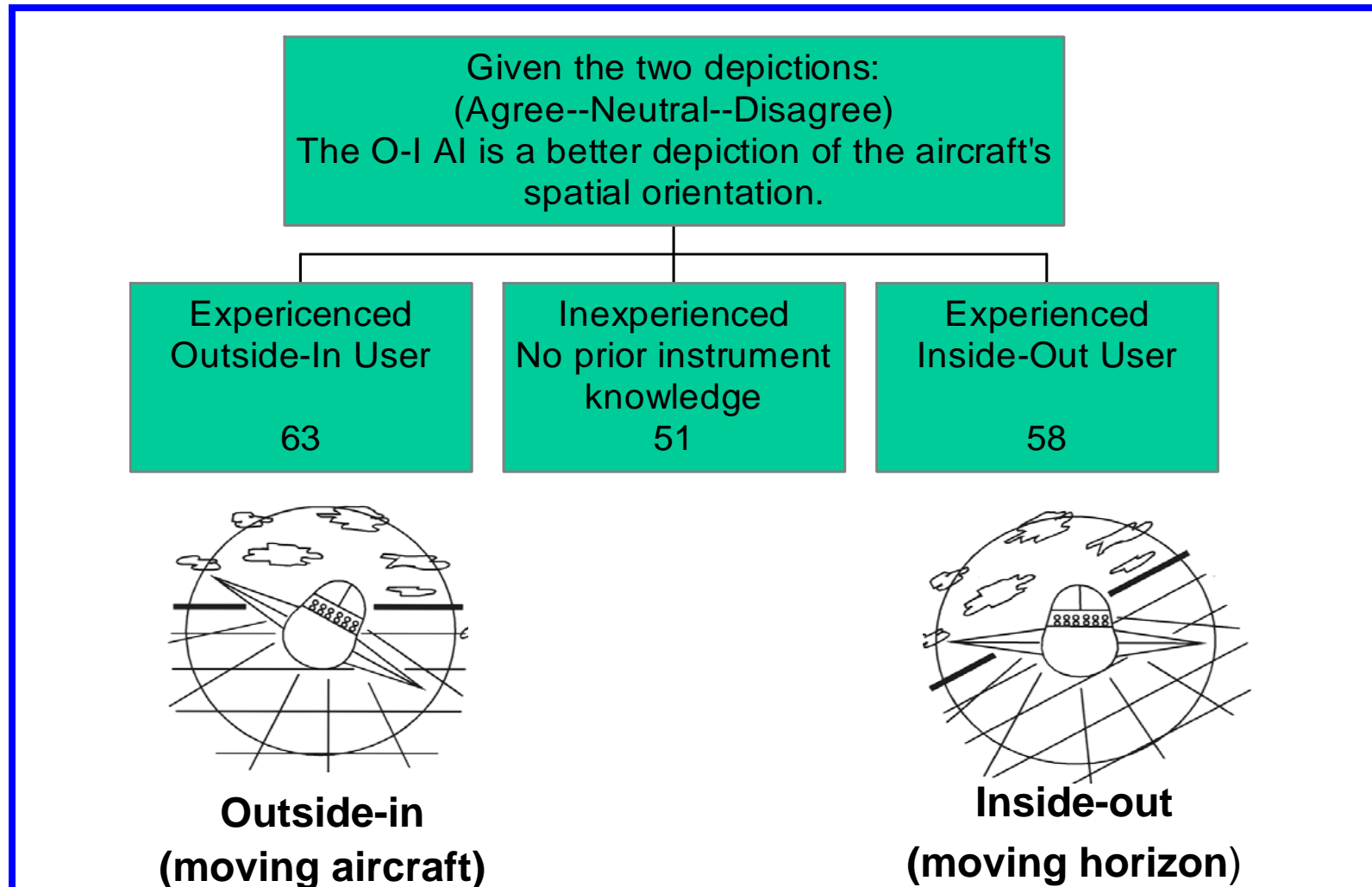
Inside-out
(moving horizon)



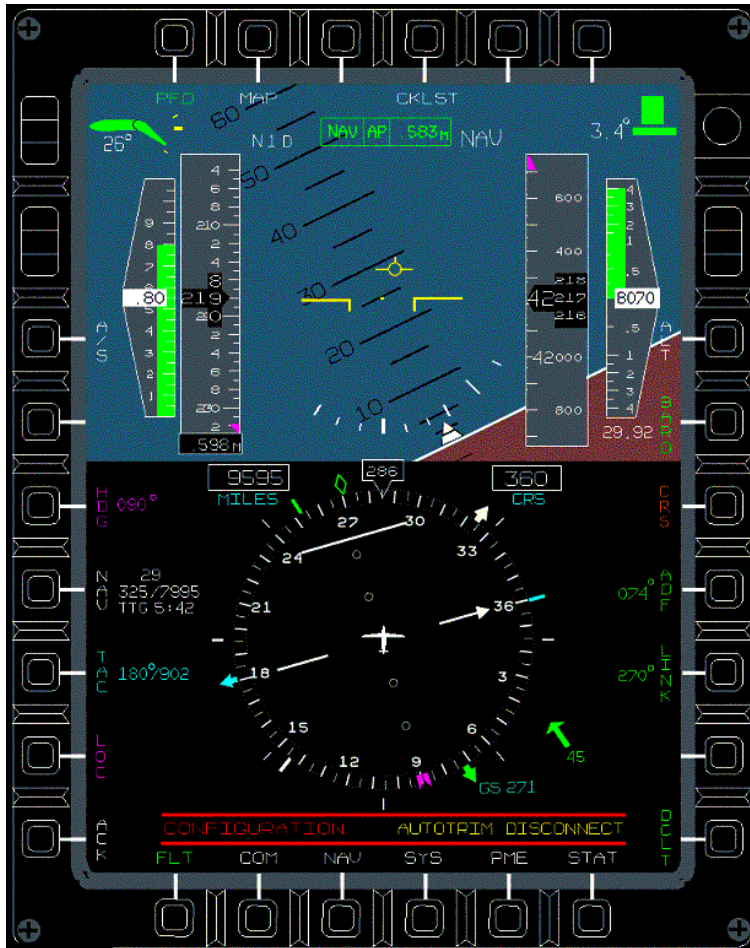
Outside-in
(moving aircraft)

Relative Motion (Stick-Display) Compatibility

Survey Structure--Pongratz & Ercoline, AsMA 99



More Display-Motion Compatibility Issues



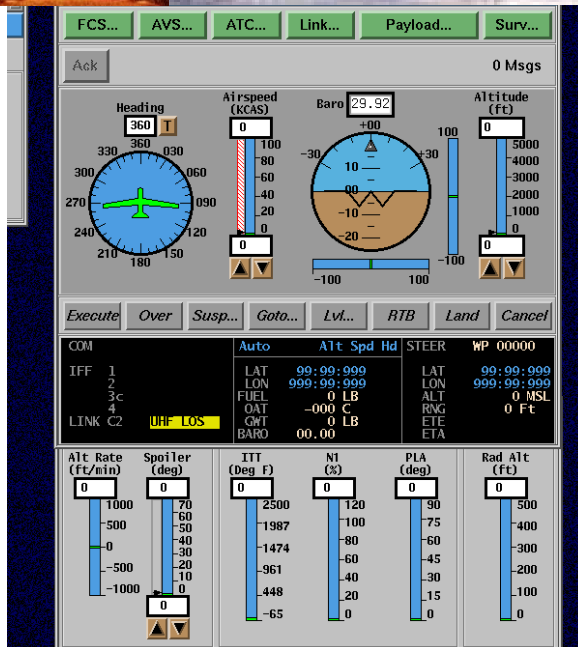
Fixed-Pointer Moving Scale versus Moving-Pointer Fixed Scale

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - Misjudgment of object-size (no size-constancy)
 - Misjudgment of object-alignment
 - Misjudgment of object-distance
 - Masking
 - Misjudgment of object-motion
 - errors of commission/omission

UAV SD CM Considerations (for PFR) Summary



- Scene content (sensor)
 - Color
 - Field of view
 - Viewing angle
 - Resolution
 - Depth perception
- Symbology
 - Color
 - Movement
 - Format
 - Time delays
 - Cognitive Filtering



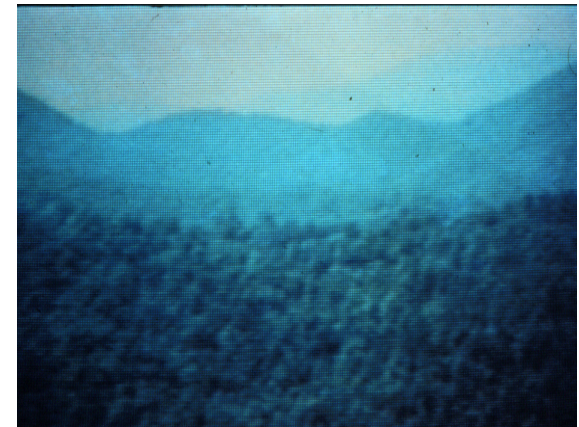
BACKUPS

Or A Mix Of All Three.



SD CM UAV Predisposing Factors

- **SD Is More Likely to Occur at Night or in Poor Visibility**
- **Visual and Non-visual Illusions Contribute Equally to SD**
- **Sparse Terrain Is More Challenging Than A Densely Vegetated One**
- **Loss Of Other Attributes Of Situation Awareness Can Lead to SD**



SD CM UAV

Three Types of SD

- Type I (unrecognized):
 - Unaware of the disorientation
 - Controls aircraft completely IAW and in response to, a false orientation perception
- Type II (recognized):
 - Aware of a conflict between internal perceptions and the aircraft instruments
 - Not necessarily recognition of SD
 - Is recognition of a conflict
- Type III (incapacitating):
 - Aware of a conflict between internal perceptions and the aircraft instruments
 - Physically incapable of making required control inputs to correct the problem

SPATIAL DISORIENTATION IN FLIGHT

Visual Cognitive Issues

- **Attitude (pitch and bank)**
 - Inside-out versus Outside-in
 - Asymmetry
 - Field of view
 - Flight path marker
- **Altitude and Airspeed**
 - Tapes versus counter-pointers
 - Roll vection
- **Cognitive Filtering**

SD CM UAV

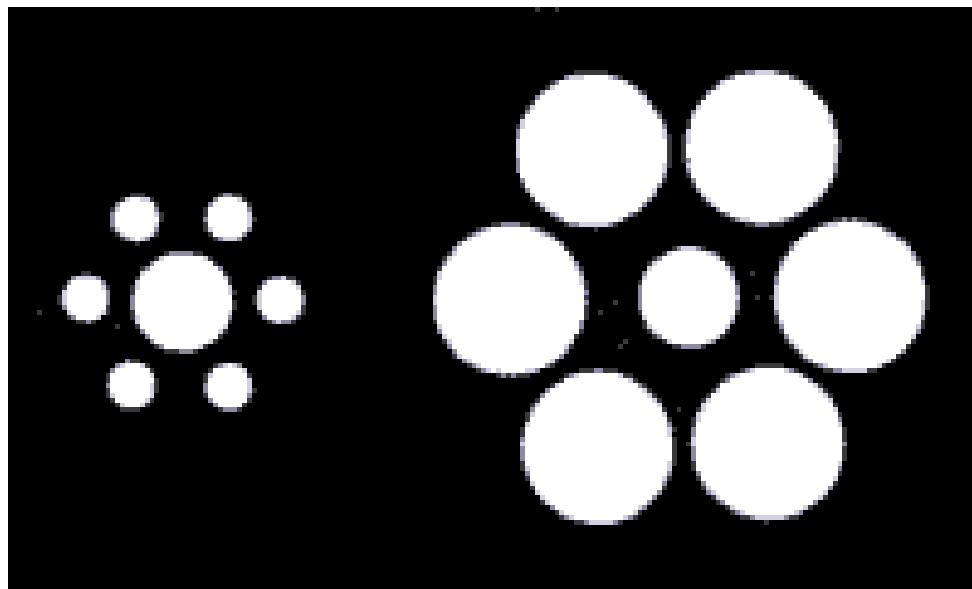
Types of Visual Issues

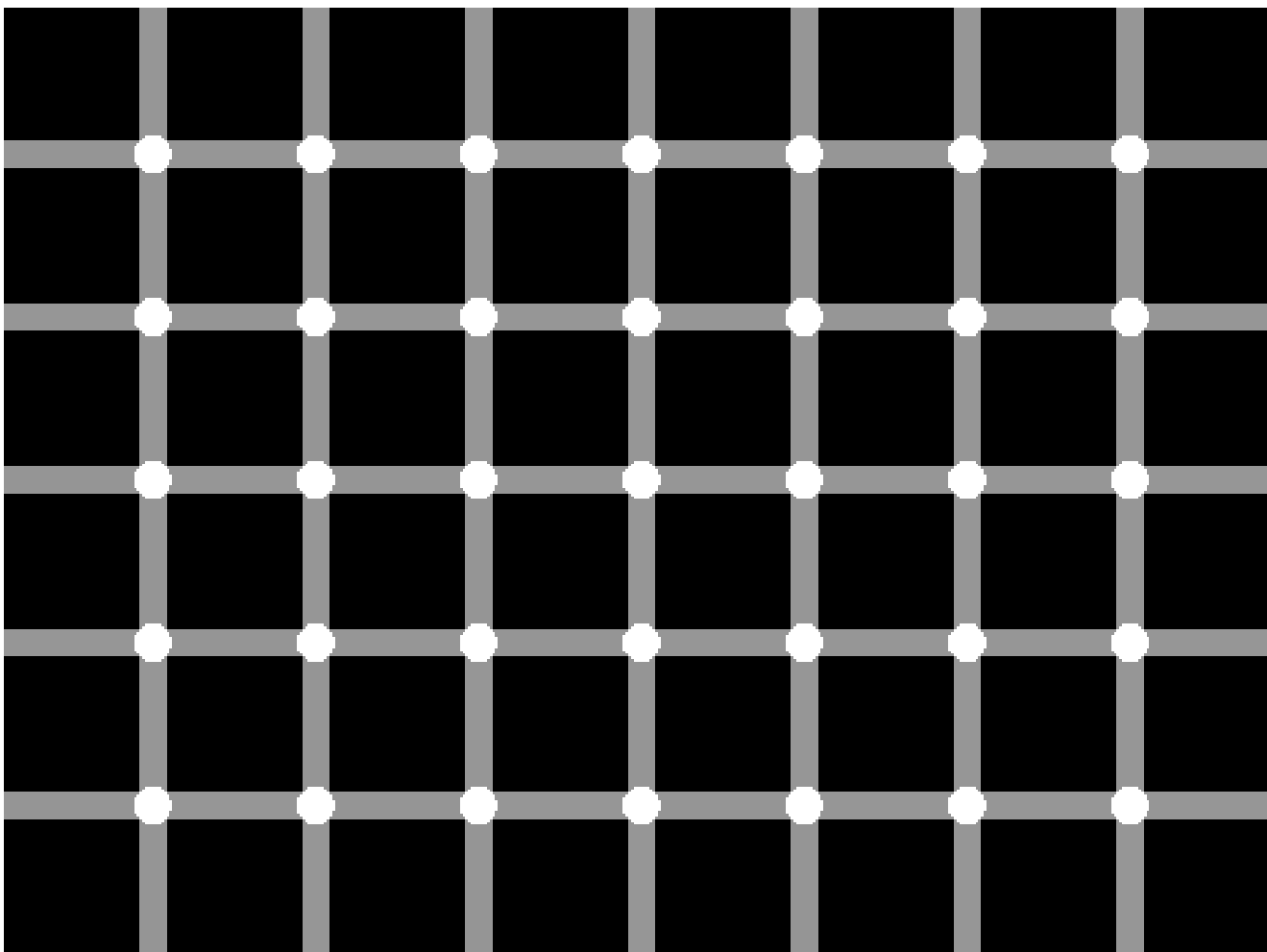
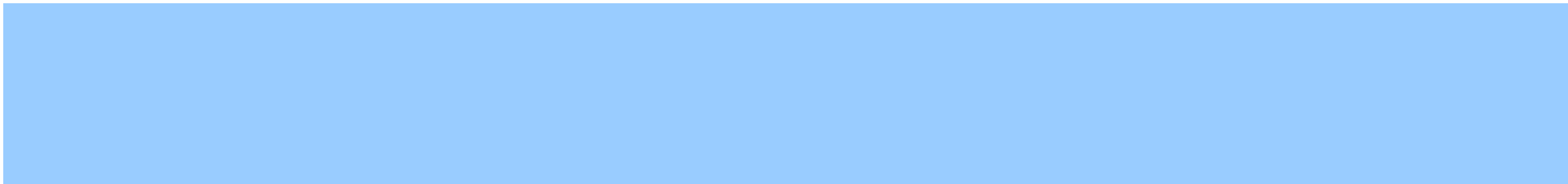
- Illusions
 - Ambient
 - Focal
 - Device
 - NVG
 - FLIR
 - LEP
- Cognition
 - Symbology
 - Attitude Recognition
 - Tapes or C-Ps
 - Standardization
 - Cognitive Filtering

Can you find the dog?

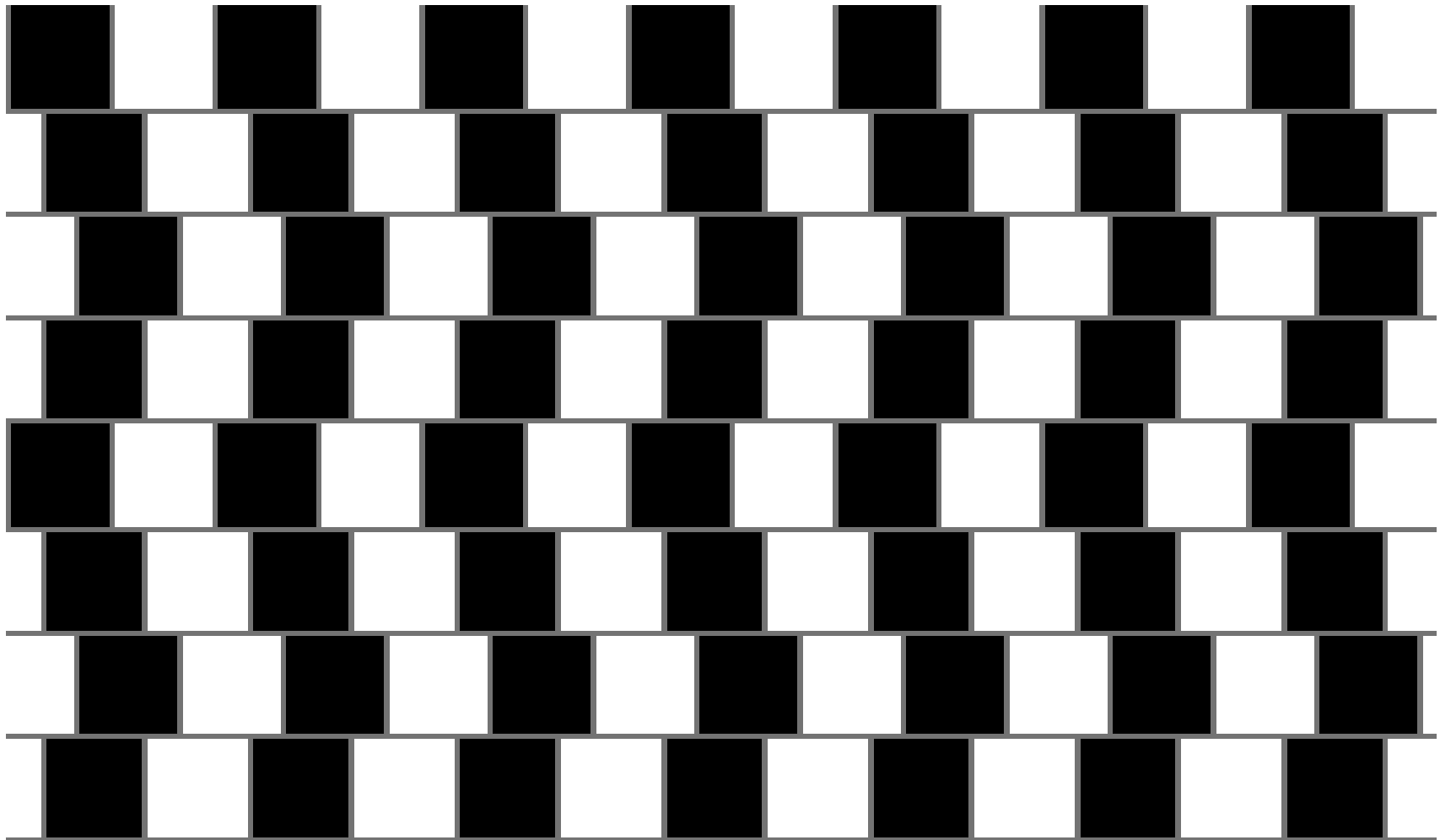


Is the left center circle bigger?





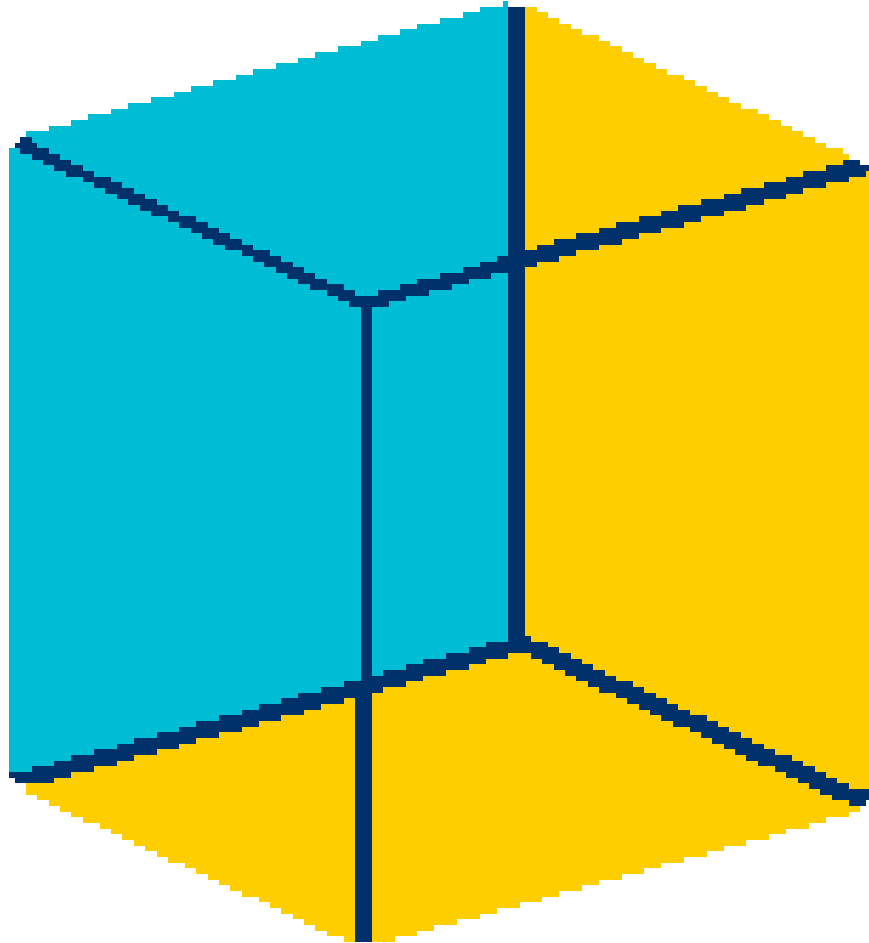
Are the horizontal lines parallel or do they slope?



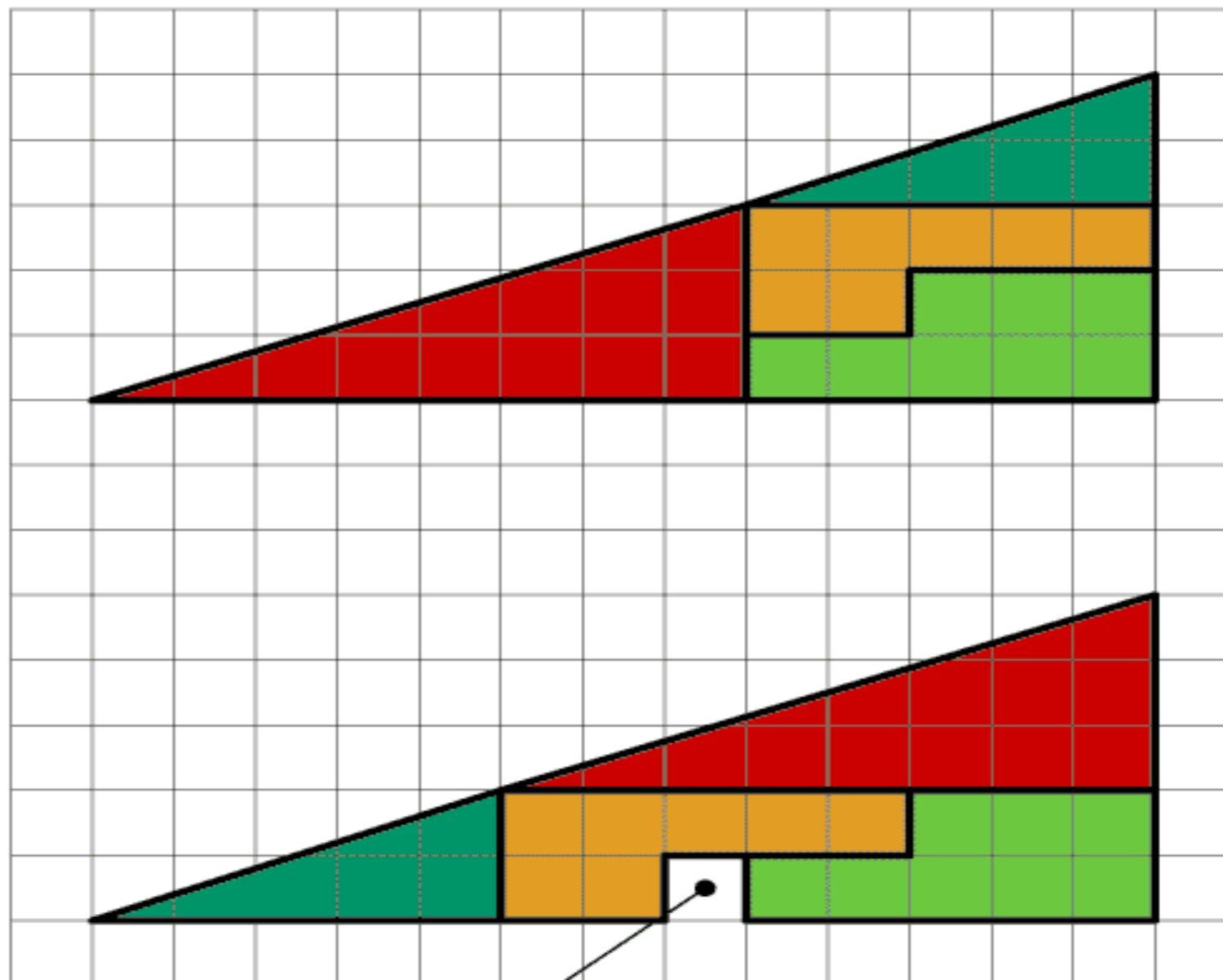
Do you see the face? Or an Eskimo?



Is the blue on the inner left back or the outer left front



HOW CAN THIS BE TRUE ?



*Below the four
parts are
moved around*

*The partitions
are exactly the
same, as those
used above*

From where comes this "hole" ?

Points to Ponder

General: a. Text changes are in red. Quickly change back by highlighting, then click on Font symbol (“A” with thick line under it) on drawing toolbar.

b. “ROA” vs “ROV” or “UAV throughout

c. All fonts changed to Arial vs some with Times New Roman

Slide 4: Don’t understand last sentence in notes.

Slide 7: Does the MRI indicate visual dominance? Do you make that point somewhere else, that it’s both good and bad? The term doesn’t show up on a slide until number 37.

Slide 8: Aural? A missing orientation cue for ROA’s. 3-D potential? Other alerts, especially when exceeding set parameters?

Slide 9 – 12: What is “CAV” in title?

Slides 13 & 14: Order? Lead in to LSA or “cognitive factors”?

Include discussion and bullet/more slides on symbology issues – CP’s vs tapes; conformal vs non; asymmetry attributes; climb/dive angle vs pitch; outside in vs inside out. How much adherence to mil-std 1787?

Slide 14: Reverse direction of arrow re: “Motor” -- consistency

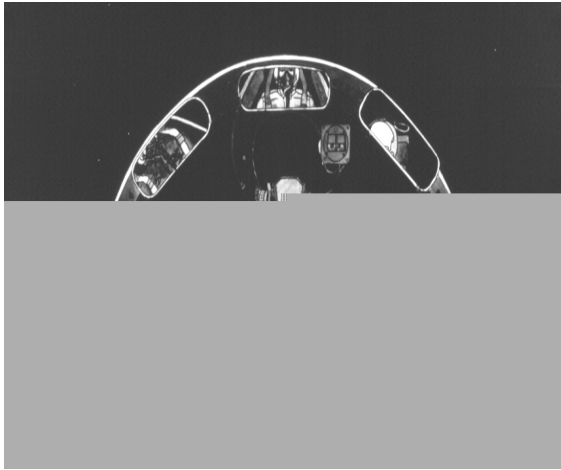
SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

- **Ambient Visual Illusions**
 - **False horizons**

VISUAL ORIENTATION ILLUSIONS

False Horizons



Shoreline



***Northern
Lights***



Sky-Ground Blending

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - **Distorted surface planes**

VISUAL ORIENTATION ILLUSIONS

Distorted Surface Planes



Sloping Cloud Deck



Sloping Canyon Walls



Rising Terrain

SPATIAL DISORIENTATION IN FLIGHT

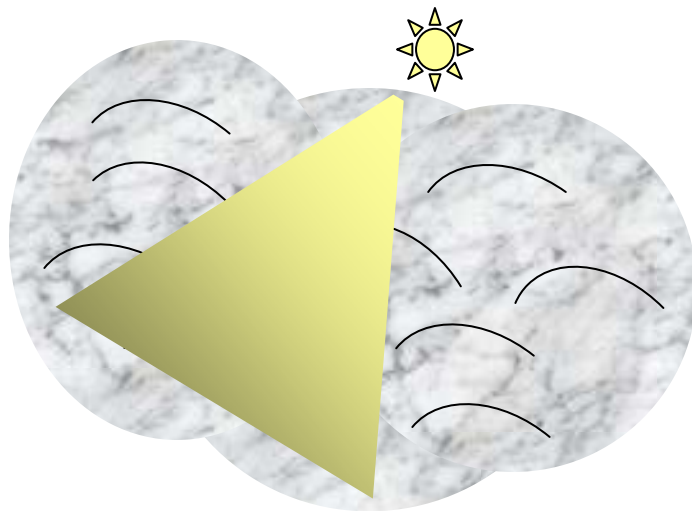
Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients

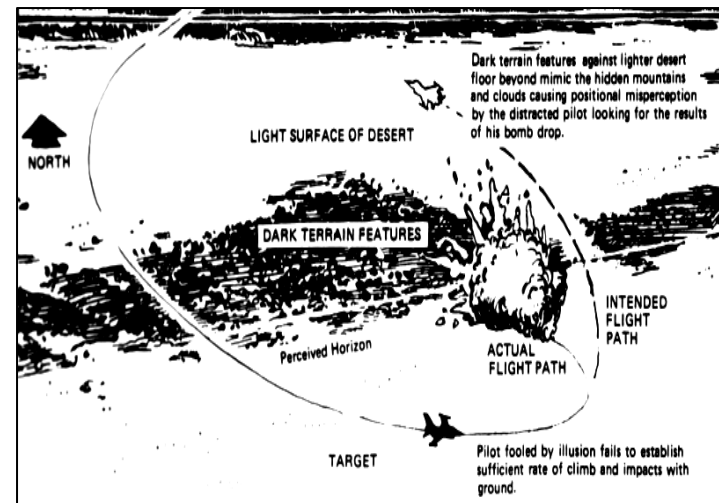
VISUAL ORIENTATION ILLUSIONS

Distorted Illumination Gradients

Sky-water inversion



Lean-on-sun



Terrain Shadowing

SPATIAL DISORIENTATION IN FLIGHT

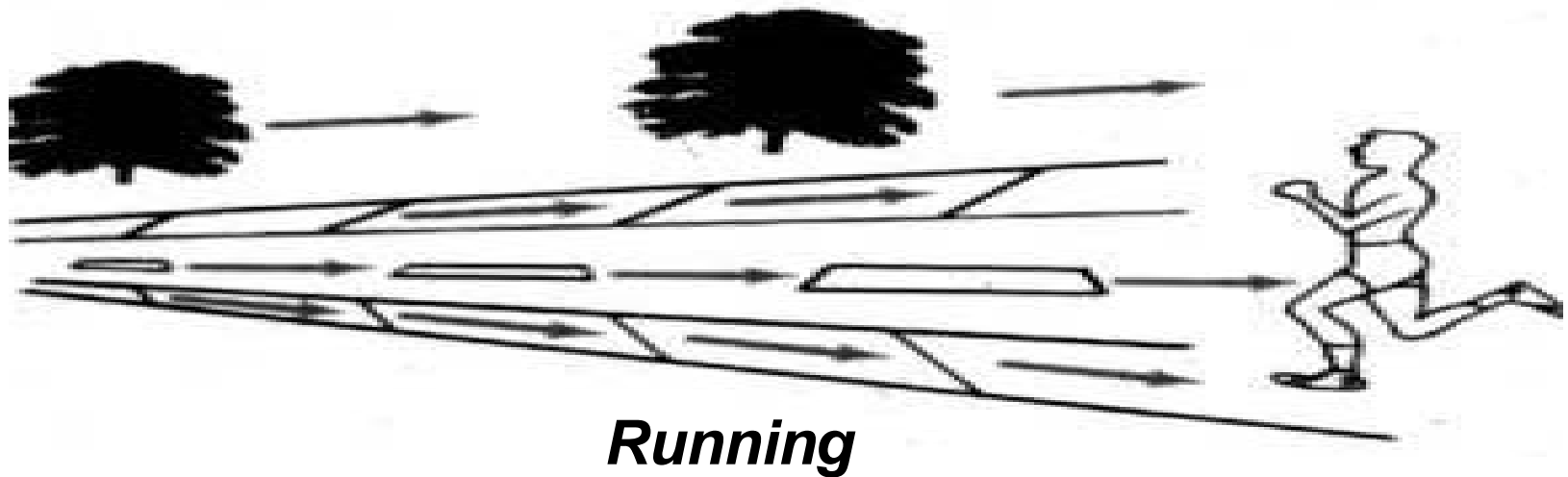
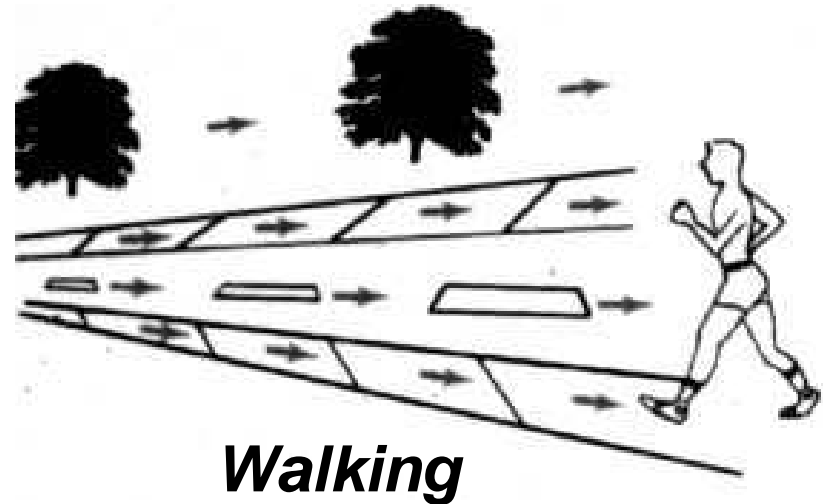
Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - **Vection ambiguity**

VISUAL ORIENTATION ILLUSIONS

Vection Ambiguity

**Optical Flow
During Terrestrial
Locomotion**



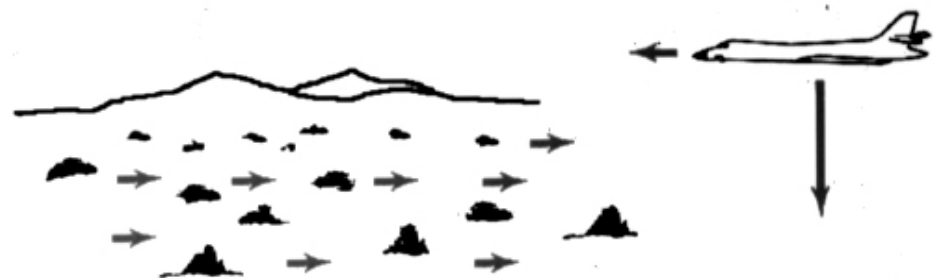
VISUAL ORIENTATION ILLUSIONS

Vection Ambiguity

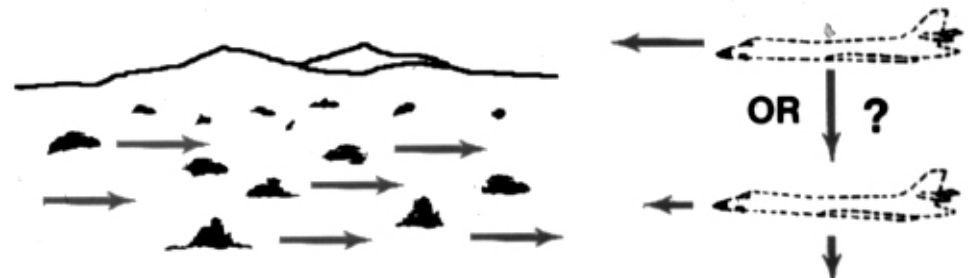
Optical Flow in Flight



*B-1 mishap (1997)
“Low and Slow”?*



High and Slow



“High and Fast” or “Low and Slow”?

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**

SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

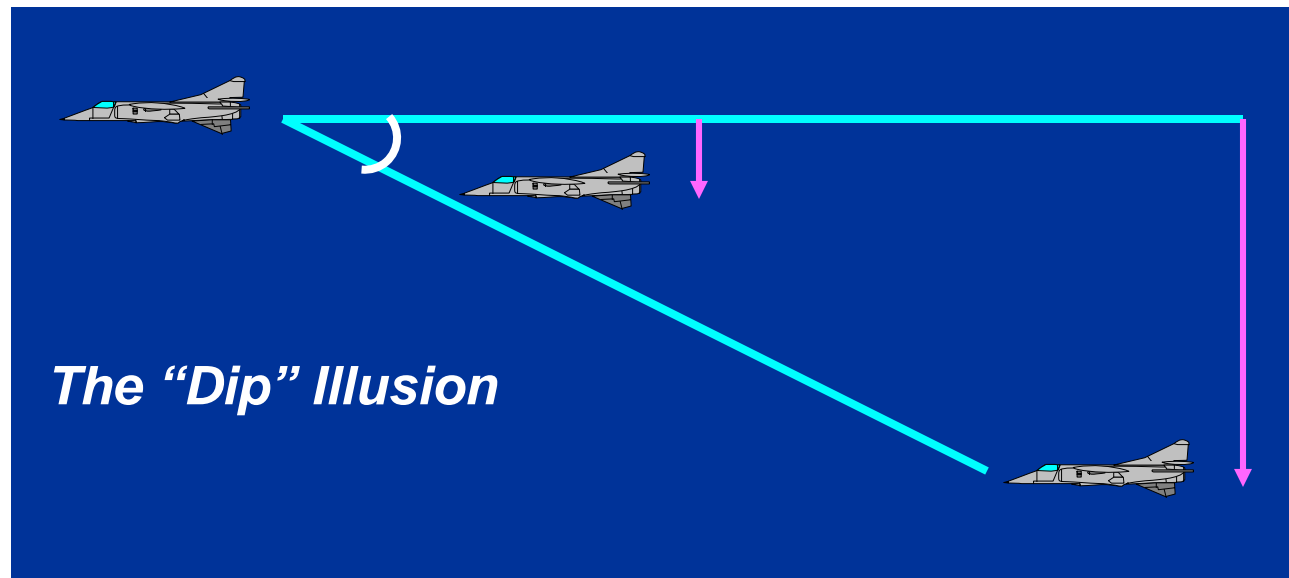
- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - Misjudgment of object-size (no size-constancy)
 - Misjudgment of object-alignment
 - **Misjudgment of object-distance**

VISUAL ORIENTATION ILLUSIONS

Formation Flying

**Formation
Flying
Leads to:**

- No earth-fixed reference
- No “visual dominance”
- Break in instrument cross-check



SPATIAL DISORIENTATION IN FLIGHT

Visual Orientation Illusions

- **Ambient Visual Illusions**
 - False horizons
 - Distorted surface planes
 - Distorted illumination gradients
 - Vection ambiguity
- **Focal Visual (Absent Ambient) Illusions**
 - Misjudgment of object-size (no size-constancy)
 - Misjudgment of object-alignment
 - Misjudgment of object-distance
 - **Masking**

VISUAL ORIENTATION ILLUSIONS

Masking

Featureless Terrain

- Desert
- Water (placid)
- Whiteout



Desert



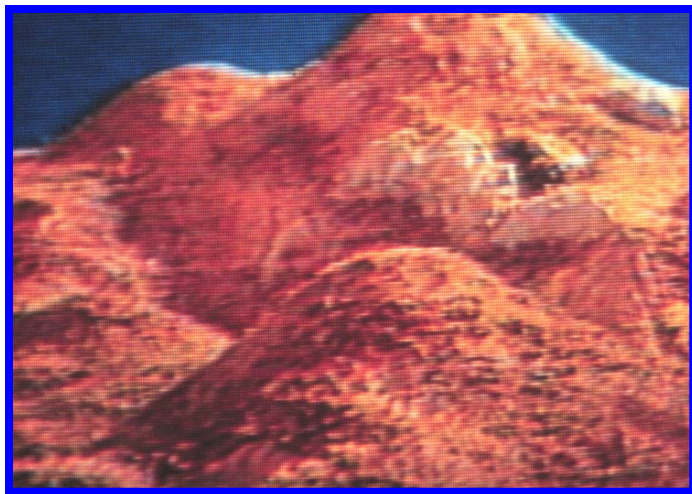
Whiteout

VISUAL ORIENTATION ILLUSIONS

Masking

Featureless Terrain

- Desert
- Water (placid)
- Whiteout



Desert



Whiteout